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UTILIZATION OF METEOROLOGICAL SATELLITE IMAGERY FOR WORLD-WIDE ENVIRONMENTAL MONITORING THE LOWER MISSISSIPPI RIVER FLOOD OF 1979—CASE 1

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UTILIZATION OF METEOROLOGICAL SATELLITE IMAGERY
FOR WORLD-WIDE ENVIRONMENTAL MONITORING
THE LOWER MISSISSIPPI RIVER FLOOD OF 1979 - CASE 1

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**UTILIZATION OF METEOROLOGICAL SATELLITE IMAGERY
FOR WORLD-WIDE ENVIRONMENTAL MONITORING;
THE LOWER MISSISSIPPI RIVER FLOOD OF 1979**

A need by policy and decision-makers for real-time or near real-time monitoring of the evolution of major natural environmental disruptions exists. With the growing realization of the need for worldwide information, a data collection technique must be identified and refined that will permit timely, repetitive environmental monitoring while bypassing issues of access restriction.

Such environmental monitoring has been proposed previously as a mission of the Landsat family¹, the proposed Landsat-D family², and of future families of active sensors such as the Shuttle Imaging Radar and its potential evolutions³.

Two of the current U.S. satellite families have the capabilities of multi-temporal, "good" spatial, and multi-band image acquisition to allow timely world-wide disaster monitoring. The older, better-known family is the experimental NASA Landsat series. This series has been proposed as a candidate for an operational system². The second satellite series is the NESS operational polar-orbiting environmental satellites (NOAA-n series). The characteristics of the two satellite series' orbital parameters, onboard sensors, ground processing and data distribution systems, and operational user requirements indicate that integrated utilization of imagery from both satellite series is feasible in a complementary mode.

As an interim and a supplement, we would like to propose utilization of imagery from the NOAA-n meteorological satellite series to monitor worldwide environmental disruptions. Previous applications of meteorological satellite families (ESSA, SMS/GOES, ITOS, TIROS, and NOAA) have been focussed primarily in the realm of atmospheric monitoring.

As a test case of environmental disaster monitoring utilizing NOAA-n imagery, we have selected the 1979 Lower Mississippi River flood. An earlier, small-scale study of the St. Louis, Missouri, area comparing ERTS-1 (Landsat) and NOAA-2 imagery has been done⁵. Similar flood studies have been done using only Landsat imagery for mapping the Red River of the North and Nimbus-5 imagery for East Australia.

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**I. CURRENT REMOTE SENSING PLATFORMS:
ADVANTAGES AND DISADVANTAGES FOR ENVIRONMENTAL MONITORING**

Within the various operational and research satellite families, two systems exist with characteristics which nearly satisfy the previously mentioned criteria. These are the operational NOAA-n series (the follow-on to the TIROS-N research satellite) and the proposed operational system. Both are designed to remotely-sense the earth from near-polar sun-synchronous orbits, to have nearly equal orbital periods, to make blind broadcasts of their multi-channel imaged data, and to record data of distant scenes for later readouts. Each system is expected to relay its distant data acquisitions via geostationary repeater satellites later in this decade. However, each satellite has been designed for different objectives: the NOAA series for daily total global coverage of atmospheric states (both day and night); and the Landsat series for detailed coverage of cloud free areas. The sensor designs produce resolutions at nadir near 6.95 sq. km. for the NOAA series and about .079 sq. km. for the Landsat series.

The NOAA-n system provides the better temporal data acquisition by viewing any given target every clear day. On the other hand, Landsat imagery provides tenfold better linear resolution, but revisits a particular target area only at 18 day intervals. This long temporal interval in Landsat imagery permits consecutive acquisitions only if clear sky conditions are also in step - an irregular occurrence.

The NOAA-n series, an operational remote sensing system underutilized by the non-meteorological community, are designed to maintain two satellites in orbit during at least the period 1979-1989. Each satellite will have a life expectancy of two to four years.

The NOAA-n satellites, like their Defense Meteorological Satellite Program (DMSP)⁴ cousins, are in a near polar orbit at an altitude of approximately 520 miles. Each satellite makes about 14.2 orbits per day and provides coverage of the entire globe twice per day, once in daylight and once during night. The two operational satellite orbits are separated by about 90° of longitude. The resolution of the NOAA-n AVHRR is 1.1 kilometer at nadir with four or five channel sensor coverage. Channels 1 and 2 are sensitive to frequencies similar to those of the current Landsats. Sensor data are recorded on board the NOAA-n satellite in two formats - local-area coverage (LAC) and global-area coverage (GAC). The GAC data are readily available for each complete orbit, but the LAC data, being very voluminous, are restricted to a maximum of a 10-minute recording per orbit. The GAC data are a quasi-summary of the LAC data. GAC is the total of four contiguous pixels, skipping the next one, then the total of the next four, etc., for the entire scanline. The next two scanlines are skipped. GAC data are archived in a digital form and are available from National Climatic Center's Satellite Data Services Division (SDSD). The LAC data must be prescheduled on a priority basis, and thus is available from SDSD only if it was initially acquired.

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The 1 km resolution data from the NOAA-n is available in two different forms. First, the High Resolution Picture Transmission (HRPT) data is transmitted on a continuous blind broadcast and is available worldwide. Reception is limited to line-of-sight between the receiver and the satellite. The other form is the LAC data. LAC is recorded on a preselected schedule and is transmitted to one of three ground control stations on command.

Multi-spectral scanner (MSS) data can be acquired from the Landsat within a near-real time frame. However, two factors exist which reduce the effectiveness of MSS data:

1. Excessive cloudiness over the desired target at time of acquisition; and
2. system design which limits acquisition of the target to once every 10 days per satellite.

The two satellite systems, Landsat and NOAA-n, have some common sensor frequencies which make it possible to compare sensor frequency combinations using the Gray-McCrory Index (GMI)¹²

. Table 1 compares the frequencies of each satellite system:

TABLE 1

NOAA Channel No.	AVHRR Span of Wave Length	LANDSAT Channel No.	MSS Span of Wave Length
1	550-680 nm	4 5	500-600 nm 600-700 nm
2	700-1100 nm	6 7	700-800 nm 800-1100 nm

A single receiving station on the globe is usually able to acquire two consecutive passes of the information from a NOAA-n satellite during the daytime hours and again for nighttime hours. The nighttime data is limited to the high number channels only. The number of daily acquisitions increases from one or two at the equator to 14 at the pole.

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The Landsat data is available to a receiving station in geographic coverage similar to that of NOAA-n. However, the Landsat image areal coverage is much less than for the NOAA-n because of the more narrow Instantaneous Field of View (IFOV). The chief advantage of the Landsat series has been high-resolution, multi-spectral imagery sufficient for fairly precise mapping of differentials of surface reflectance. Previous high-quality Landsat imagery mapping has included bathymetric studies, urban, and rural, land-use discrimination, geologic mapping, coastal zone, characteristic definition, pollution, studies, hydrologic and ice-mapping, and agricultural studies.

Problems with the current Landsat system vis-a-vis user requirements have begun to arise with the electronic degradation of both the space-borne sensors and the ground-processing system. This degradation with age is only to be expected when it is realized that Landsat-2 and 3 were launched in 1975 and 1978 with expected satellite lifetimes of one year. The present Landsat ground-processing system is a custom-designed, composite, experimental system that has borne up well although subjected to heavy operational use requirements.

For some user requirements, Landsat MSS target acquisition repeatability every 9 days (2 satellite system)/18 days (1 satellite system) is now marginal. This repeatability becomes critical when cloud cover over a desired target prevents an acquisition. This now results in a minimum 18-day MSS image repeatability. These temporal gaps are particularly frustrating to time-dependent agricultural, vegetation, hydrologic, and ice-cover monitoring studies. Although cloudiness affects target acquisitions for both Landsat and the NOAA-n systems, the wider IFOV of the NOAA-n designed for total global coverage usually provides useful agriculture target coverages as often as four to eight times in an eighteen day period.

The launch of the Landsat-D family (currently scheduled for the summer of 1982) will provide continuity for the Landsat MSS image archive. Such continuity assumes that the MSS aboard current Landsats remains operational until that time. As of this writing, Landsat-D will carry both a four-band MSS and seven-band MSS (Thematic Mapper). Workup of a new ground processing system rated for operational use also is underway at this time. The Landsat-D family satellites will be Shuttle-recoverable, allowing refurbishment of onboard expendables and maintenance/updating of onboard sensors and electronics. The Landsat-D system, as currently funded, will consist of two satellites in orbit. This will allow 8-day (16-day single satellite repeatability) image acquisition cycles. The potential problems of cloud cover interfering with this repeatability remain. The cloud cover problem must await the arrival of "smart" tiltable sensors and active microwave systems such as the proposed Landsat-H, GEOSAT, MAPSAT, etc., systems.

II. SELECTION OF THE 1979 LOWER MISSISSIPPI VALLEY FLOODS

In an attempt to fill the temporal gaps of Landsat imagery cycles, we have investigated the possibility of using the NOAA-n environmental satellite family imagery for timely, repeatable acquisition of data for assessing vegetative health using the Cray-McCrary Index (GVI), and now, for disaster assessment.

For our first disaster assessment study, we have selected the floods along the Lower Mississippi River and its tributaries during the late spring of 1979. Reasons for this selection were easy geographic access for ground truth, availability of high-quality surface meteorological and hydrologic data, availability of NASA aircraft strip photography, and the assumption of Landsat imagery availability.

The last assumption proved unfounded. No acceptable Landsat MSS imagery for the target area exists for the flood crest period of 15 April-31 May 1979. This is due to intermittent cloud cover coinciding with Landsat passes over the region. As a result, Landsat imagery from the 1977 floods in the same region were used for imagery comparison purposes. Table 2 illustrated the problem of Landsat imagery continuity in this case.

As a comparison to the Landsat regional imagery acquisition history during the April-May 1979 period, an incomplete inventory of NOAA-n imagery available from 27 April through 15 May for regional flood assessment is presented in Table 3.

The TIROS-N (NOAA-n) image of the Lower Mississippi Valley on 5 May 1979 (orbit 2297) was selected for detailed analysis (see Figure 1). Mid-point on the image is a north-south line from approximately Brownsville, Texas, to Wichita, Kansas. Mid-point on the image is pixel 1924. The image is 2048 pixels wide (east-west). The target area of North Louisiana and South Arkansas runs from pixel 361 to pixel 587. Despite this bias of the study area towards the eastern edge of the image, few problems with geometric distortion were encountered.

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TABLE 2

LATE SPRING 1979 REGIONAL LANDSAT PASSES ¹			
ACQUISITION DATE	PATH-ROW	ACQUISITION AVAILABLE	CLOUD COVER (%)
April 5	25-37	NA ²	--
April 5	25-38	NA	--
April 6	25-37	L-3	10 ³
April 14	25-37	L-2	6 ³
April 14	25-38	L-2	6 ³
April 15	25-37	L-2	10 ²
April 23	25-37	NA	--
April 23	25-38	NA	--
April 23	25-37	NA	--
May 2	25-37	NA	--
May 2	25-38	L-2	90
May 3	25-37	NA	--
May 11	25-37	L-3	90
May 11	25-38	L-3	90
May 12	25-37	L-3	90
May 20	25-37	L-2	90
May 20	25-38	L-2	70
May 21	25-37	L-2	90
May 29	25-37	NA	--
May 29	25-38	NA	--
May 30	25-37	L-3	90

¹From U.S. Department of Interior Landsat archive at ERCS Data Center, Sioux Falls, SD.

²Neither satellite (Landsat-2 or -3) turned on due to cloud cover forecasts.

³Flooding and flood crests had not arrived in area during this period.

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TABLE 3

LATE SPRING 1979 REGIONAL NOAA-n IMAGERY REVIEWED ¹			
ACQUISITION DATE	CHANNELS	CLOUD COVER (%)	ORBIT
April 27	1-4	0	2763
April 28	1-4	20	2777
April 29	1-4	80	2798
April 30	1-4	50	2805
April 31	1-4	80	2812
May 1	1-4	20	2819
May 1	1-4	100	2826
May 5	1-4	40	2876
May 6	1-4	0	2890
May 6	1-4	10	2897
May 7	1-4	0	2904
May 8	1-4	30	2925
May 14	1-4	0	3003
May 15	1-4	0	3017
May 15	1-4	0	3024

¹ From Satellite Data Services Division (National Climatic Center), World Weather Building, Washington, DC

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FIGURE 1

CAPTION

Full NOAA (TIROS-N) image used in this study. The coast of Texas is well-defined until the cloud area intercepts the coast over Galveston. The study area transects the color/shade difference across the Mississippi River.



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III. REGIONAL GROUND DATA CONCERNING THE FLOOD

The 1979 floods in the Lower Mississippi Valley watersheds rank with the 1973 and 1927 floods as the greatest floods of the 20th century in Louisiana¹². Comparisons with the 1927 flood are not germane for remote sensing comparison. Direct comparison is quite difficult because of the lack of early imagery and because of man-modifications to the entire river system during the intervening half-century. On the other hand, surface data on flooding patterns in 1973 and 1979 were quite similar. Thus, we felt the regional flood patterns imaged by Landsat in 1973 should be similar to those imaged by NOAA-n in 1979.

Meteorological and hydrologic patterns during all three flood years were similar - a wet autumn, heavy Mid-West winter snowpack averaging 18-30", quick spring thaw, and heavy rain in the lower reaches of the Mississippi watershed.

In January 1979, a record snowpack was laid down in the Western and Southern Great Lakes states and watersheds. During February, the Great Plains averaged 300% of normal precipitation totals. A rapid snowmelt throughout the Midwest began 11-12 March. Flooding along upper Mississippi River watersheds began during mid and late March. These waterway crests coalesced along the mainstream of the Mississippi River in late March and early-mid April.

The mainline Mississippi crests were increased and compounded by continuous heavy rains throughout Louisiana, Arkansas, and Mississippi from December 1978 until mid-May 1979. The runoff from these six-month regional rains (see Table 4) averaging 45 inches resulted in flooding along the courses of local waterways, and backwater flooding at their confluence with the Mississippi River.

The result of the heavy rain, saturated ground, rapid snowmelt of a deep snowpack, and the natural reservoir of backwater flooding behind main-line levees were long, flat compound crests on area waterways. River stages during the period for representative regional Lower Mississippi River and the Ouachita River stations are summarized in Table 5.

Other waterways in flood between the Ouachita and Mississippi Rivers included the Ecouf and Tensas Rivers, Bayou Bartholomew, Bayou DeSiard, Bayou Macon, and Bayou LaFourche. Backwater flooding was extensive in area swamps and land normally under cultivation. Most of this standing water behind levees and bankful waterways had run out by the end of the first week of June.

TABLE 4

REPRESENTATIVE 6-MONTH PRECIPITATION TOTALS,
ARKANSAS AND LOUISIANA¹

Precipitation (Inches)

Location City/State	Dec 1978	Jan 1979	Feb 1979	Mar 1979	Apr 1979	May 1979	TOTAL	Dec-May Norm
Camden, AR	6.82	7.55	5.57	4.25	10.51	7.57	42.27	23.87
Crossett, AR	5.32	11.47	5.14	6.39	15.68	8.10	52.10	36.76
Eldorado, AR	9.31	3.52	5.42	5.49	7.79	6.97	43.50	29.31
Helena, AR	10.91	6.78	4.65	5.84	10.80	13.96	52.94	29.29
Little Rock AR	11.56	4.85	5.67	3.10	9.64	22.65	45.56	27.85
Monroe, LA	10.29	12.72	8.31	5.34	9.12	6.66	52.44	29.12
Sheridan, AR	10.10	4.48	5.93	3.28	9.76	14.20	47.74	29.04
St. Charles, AR	9.55	7.70	4.49	5.12	11.47	13.60	51.93	28.93

¹ Data taken from National Weather Service Climatological Data series for Arkansas and Louisiana and Monthly Weather Summary series of the Climatic Research Center, Northeast Louisiana University, Monroe, Louisiana.

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TABLE 5

REGIONAL MISSISSIPPI AND OUACHITA RIVER STAGES,
APRIL-MAY 1979

Date	Miss R. at Greenville ¹ MS	Miss R. at Vicksburg ² MS	Miss R. at Natchez ³ MS	Ouachita at Camden ⁴ AR	Ouachita at Monroe ⁵ AR
April 2	47.9	42.6	49.7	25.4	36.5
April 9	49.6	43.4	49.8	31.9	37.6
April 16	52.8	45.6	51.9	33.0	40.0
April 23	53.2	47.3	54.6	25.4	42.1
April 30	53.5	47.7	54.5	31.4	44.2
May 6	51.1	46.0	53.4	31.2	44.5

¹ Flood stage 48.0 ft; crest 54.1-54.2 ft, 26-28 April.

² Flood stage 43.0 ft; crest 47.9 ft, 26-29 April.

³ Flood stage 48.0 ft; crest 54.6 ft, 23-29 April.

⁴ Flood stage 26.0 ft; major crest 33.2-34.5, 26-29 April

⁵ Flood stage 40.0 ft; crest 44.9 ft, 10-17 May.

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IV. DISCUSSION OF NOAA IMAGERY

No acceptable Landsat imagery is available for the regional peak flooding period of mid-April through mid-May 1979. However, a Landsat image color composite (Figure 2a) for the 1973 flooding along the Mississippi, Ouachita, and Red Rivers was acquired. The pattern of the 1973 flooding as imaged by Landsat is similar to that known from 1979 surface data.

In the 1979 circumstance the major difference from the 1973 flood is that flooding along the course of the Red River was not of great duration or extent. Therefore, it was decided to compare areal patterns of water cover returns primarily for the Ouachita and Mississippi drainage basins in North Louisiana and South Arkansas. The narrow purpose of the comparison was to establish whether flood mapping could be done effectively using NOAA-n imagery with ground data as a control.

The NOAA-n image selected for detailed analysis is that of 6 May 1979, orbit 2897. (Regional expansion of the entire acquisition (Figure 1) is Figure 2b.). Thirteen scanlines on the image from Western Mississippi to Eastern Texas were selected for detailed analysis using the Gray-McCrory Index (GMI). The GMI was developed originally for analysis of vegetation vigor as expressed by greenness (channel 2 minus channel 1)¹². The GMI also classes cloud and water returns.

The GMI analyses of the NOAA-n image scanlines are presented as a composite graph (Figure 3). One of us (M.R.H.) ran the eastern half of the thirteen scanlines on the ground during the flood periods of 1975, 1977, and 1979, to evaluate flooding extent and duration. In addition, the southernmost scanline and the Gran Mal area (confluences of Ouachita and Saline Rivers) were ground-photographed in February and March 1981. These last trips were to determine the cause of mixed and anomalous pixel returns in areas that are topographically low. A regional map is presented in Figure 4. The mid-scale NOAA-n image for map comparison is Figure 5.

Comparison of ground data with the thirteen May 6, 1979 NOAA-n scanline GMI's, the 1973 Landsat image, and regional topographic maps show:

- a. ready identification and crude classification by GMI value of land, water, and cloud-covered regions;
- b. the potential for mapping and acreage estimates of each GMI class;
- c. and surprising geometric constancy across the NOAA-n image.

Figure 3 is a composite graph along scanlines of the GMI's. They are plotted for about one-fourth of a complete scan and are for the area from 90°W to 94.5°W as indicated along the abscissa of the graph. The ordinate is the GMI value in deltas of four.

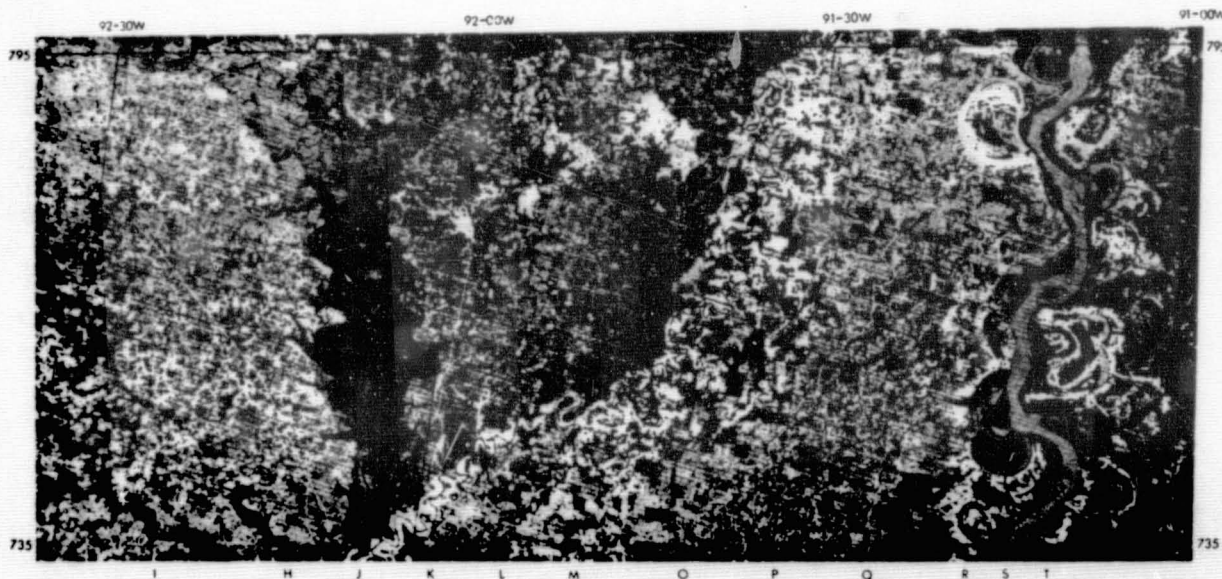
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FIGURE 2a

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Landsat color composite of study area (31 March 1973). Mississippi River in flood is on the right (east) bounded by the red finger of the Macon Ridge on the western edge of the floodplain. The large lake in the western third is the ephemeral flood impoundment of the Ouachita River upstream from Monroe, Louisiana.

COLOR COMPOSITE LANDSAT TM-2
31 MARCH 1973

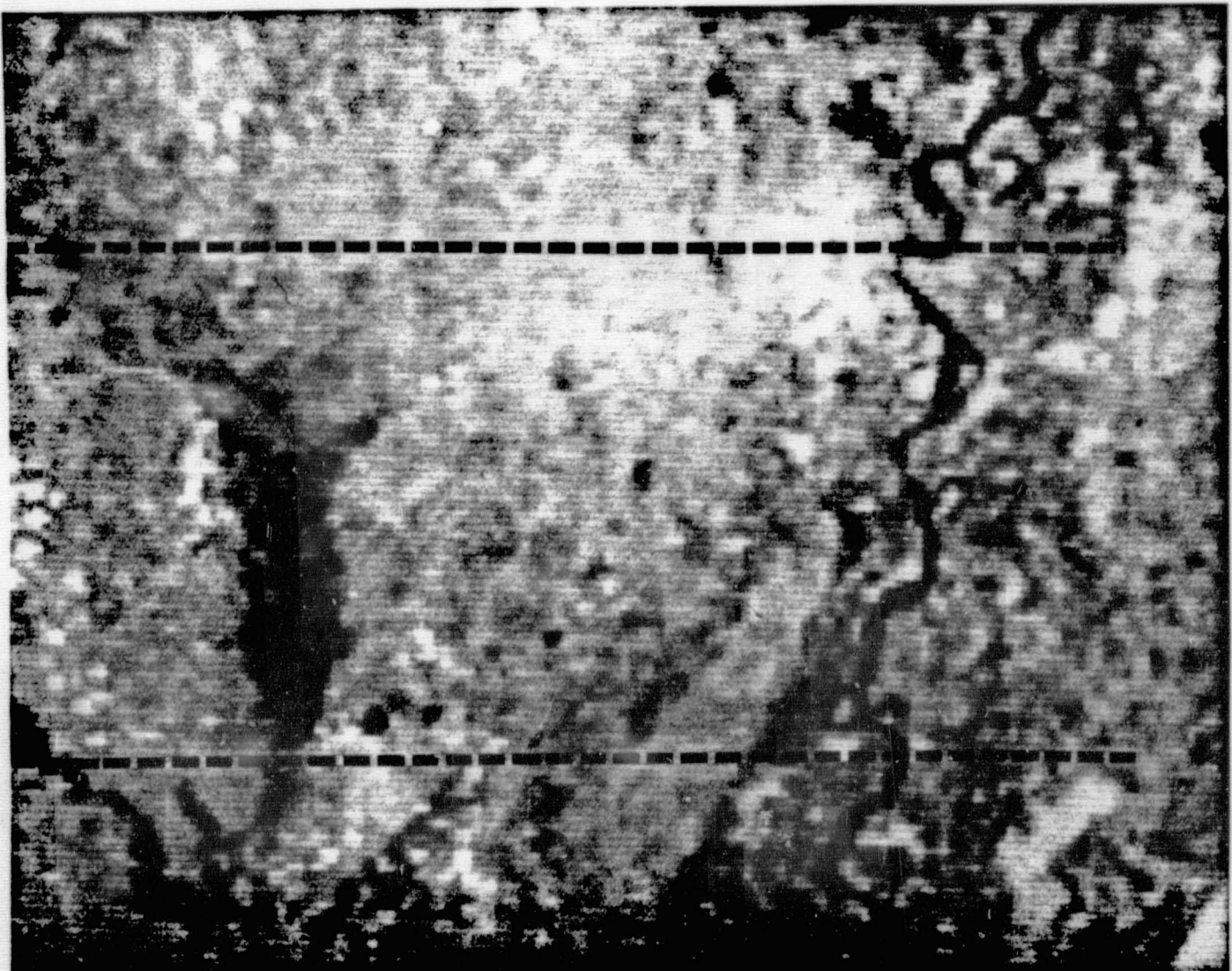


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FIGURE 2b

CAPTION

NOV-n image (6 May 1979) of approximately same area as in Landsat image. False colors assigned by pixel CMI value. Blacks and dark blues represent negative values grading to tans for higher CMI values. A few scattered clouds are seen as white pixels.



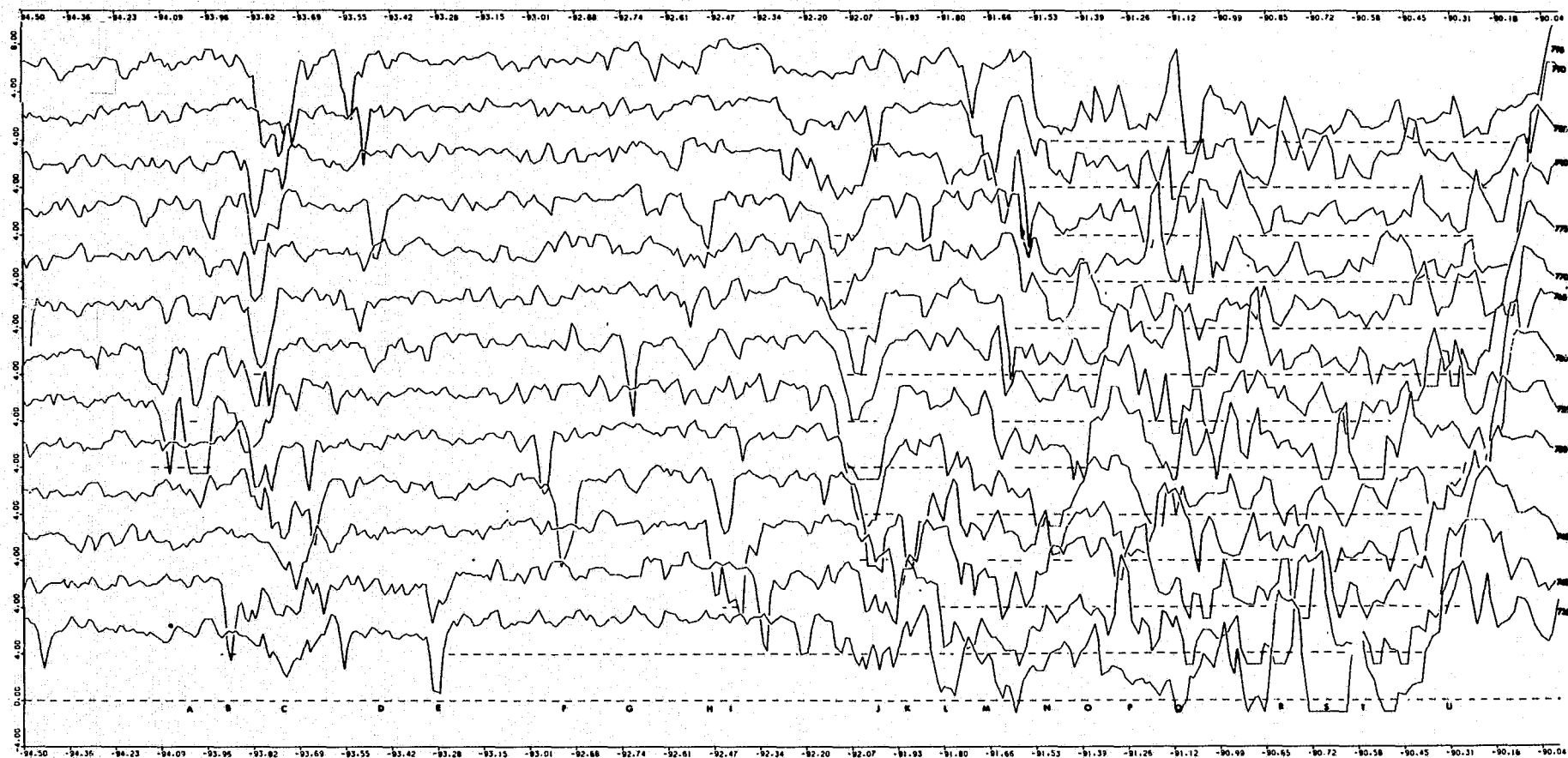


Figure 3

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FIGURE 3 - LEGEND

MAJOR GEOGRAPHIC FEATURES

(SCANLINES 795-735)

<u>LTR</u>	<u>FEATURE(S)</u>	<u>SCANLINES</u>	<u>WEST LONGITUDE</u>
A	Caddo Lake, Louisiana and East Texas	770-750	94.1-93.9
B	Cross Lake, Louisiana	740	93.9-93.3
C	Red River, Arkansas and Louisiana Note western levees with standing backwater especially prominent at scanlines 785-775	795-735	93.9-93.6
D	Lake Erling, Arkansas Murray Lake, Louisiana Bayou Bodcau Reservoir and Floodplain These three water storage areas comprise a unified water shed.	795-790 780 775-750	93.6-93.5 93.5-93.4 93.5-93.6
E	Upper Lake Eistineau, Louisiana	740-735	93.3
F	Lake Claiborne, Louisiana	755-750	92.8-93.0
G	Corney Lake, Louisiana	765	92.7
H	Bayou D'Arbonne and Lake	785-755	92.6-92.4
I	Bayou D'Arbonne Floodway	750	92.5-92.2
J	Grand Marais (known locally as the Gran Mal Swamp) - Junction of Quachita and Saline Rivers. This Quachita River floodway forms a large lake for 2-6 months during major flood years.	795-745	92.3-91.9
J	Quachita River main course below Sterlington, Louisiana.	745-735	92.1-91.9
J	Backwater flooding and levees prominent on both scanlines.	745-735	92.31-92.32

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K	Saline River prior to junction with Quachita River	795-796	92.6-91.9
L	Bastrop Ridge and east bank levees of Quachita River	795-735	92.8-91.9
M	Bayou DeSiard	795-740	91.9-91.6
N	Bayou Bartholomew, Little Bayou Boeuf, and Bayou LaFourche	795-735	91.6-91.4
O	Boeuf River	795-735	91.5-91.1
P	Macon Ridge	775-735	91.6-91.1
Q	Bayou Macon	795-735	91.1-90.8
R	West bank levees of Mississippi River	795-735	90.9-90.6
S	Main channel of Mississippi	795-735	90.8-90.5
T	East bank levees of Mississippi River	795-735	90.6-90.4
U	High loess bluffs delimiting eastern edge of Mississippi River floodplain	795-735	90.4-90.0

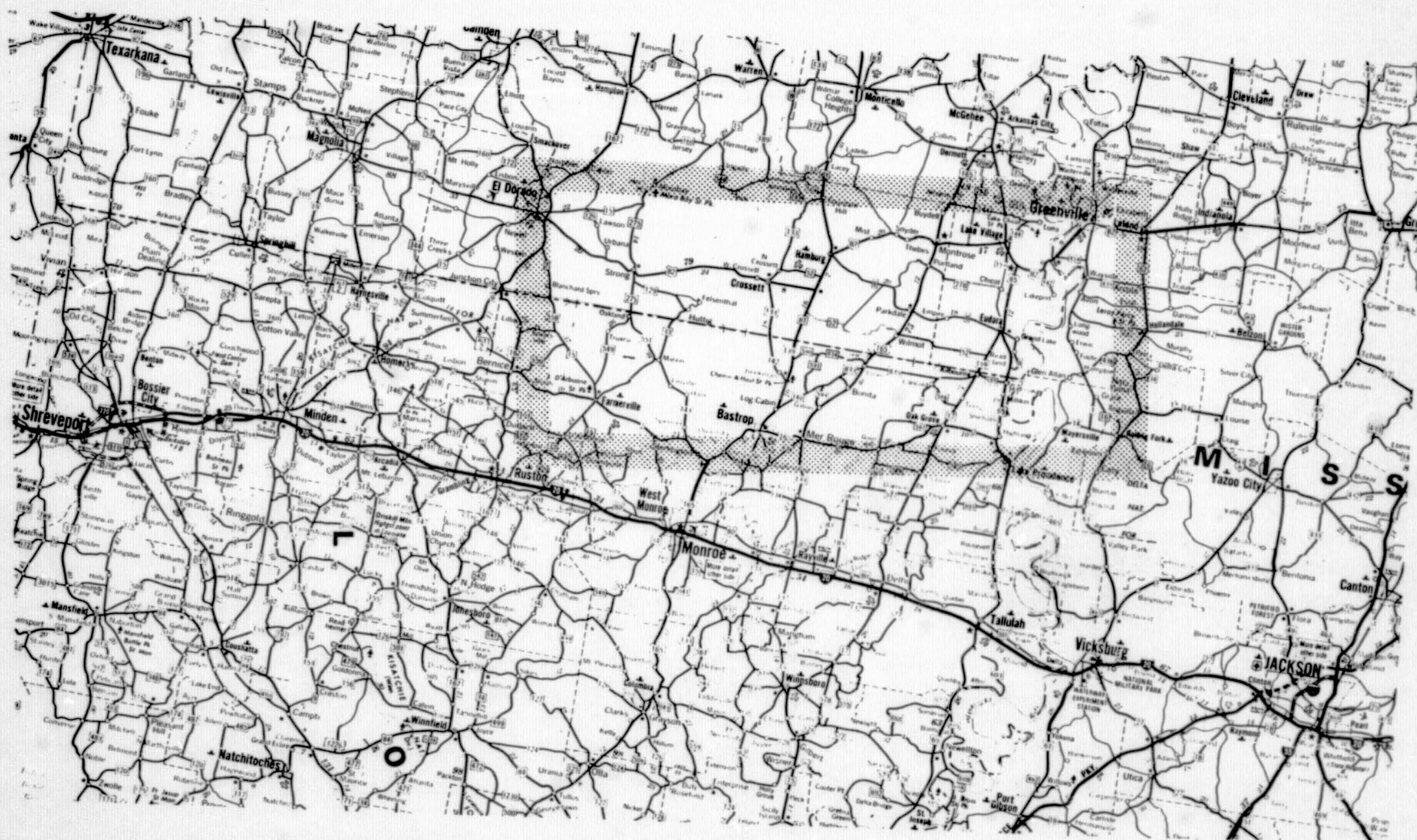


FIGURE 4

Orientation map of study region. Areas depicted in Figures 2a and 2b are bounded by hatched box.

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FIGURE 5

CAPTION

Mid-scale blowup of Figure 1 showing major geographic features detectable in NOAA-n imagery. Mississippi floodplain, averaging 60-100 miles in width is the broad north-south blue stripe to the east. The courses of the Arkansas, Red, and Ouachita Rivers and the Grand Mal Swamp are clearly defined. The dark wavy stripes south of the Arkansas river are the north-facing slopes of the various mountain groups of the Ouachita Geosyncline in Central Arkansas and Eastern Oklahoma. All NOAA images pictured in this study were taken with a 35-mm camera in front of a CRT.



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GMI's of water and clouds are characteristically negative when the entire pixel is in water or cloud. In cases where the pixel area is mixed water and vegetation, the GMI has a depressed value. A table of preliminary GMI classifications based upon limited data is presented in Table 6.

The 1 kilometer resolution of the NOAA-n limits the size of the target that can be identified. Small lakes of about one mile in diameter can be detected by a negative spike on the graph caused by a mixed pixel. An example of this is found on the graph of scan line 755. A low GMI (0.46) is found at $92^{\circ} 42.6'W$ $32^{\circ} 57'N$. This pixel is found to be that of Lake Corney in Northern Louisiana. At $93^{\circ} 59'W$ on scan line 755 we find very low GMI is an area that has GMI values of 6-7. This position coincides with that of Lake Claiborne. In both of these cases, the spikes on the graphs were very pronounced, but did not have a negative value. This is because the lakes were not of sufficient size to generate a pure water return.

The graphs of GMI in the area of the Mississippi River indicates many mixed, depressed values, and pure water returns with negative values. It was initially expected that the flooded area would be all negative. In previous NOAA-6 scanline runs, GMI's over large, uninterrupted bodies of water such as the Gulf of Mexico will give all negative values.

The mixed pixels from the flooded areas were determined to be in an area where the vegetation was above the surface water height, such as mixed cypress-oak bottoms. In addition, this area is populated by a dense concentration of Paleo-Indian mounds and old natural levees.

Thirteen scanlines spaced 5 km apart were plotted from the 6 May 1979 NOAA-n image and then analyzed for GMI determination (Table 6). These lines include an area from Mississippi to Texas (Figure 3). We concentrated our investigation on the areas in northeastern Louisiana and southeast Arkansas.

The main geographic features from east to west are the Mississippi River; Macon Ridge; a low area of crop land between the Boeuf River and Bayou Bartholomew; the Ouachita River valley including the Grand Mal swamp; and two flooded bayous - Bayou de Loutre and Bayou D'Arbonne - dissecting the hills of North-Central Louisiana.

The contoured analysis of the GMI's clearly depicts these features when compared to the 1973 Landsat pictures and regional topographic maps. Several GMI anomalies are apparent and require explanation. First is the low crop land between the Boeuf River and Bayou Bartholomew. This area has few negative values of the GMI. However, the flood area just west of the Boeuf River is well defined. Bayou Bartholomew does not stand out on the GMI's as it does in the 1973 Landsat image. Even on the Landsat image it does not appear to cover a very wide area. This bayou is narrow and very winding. This results in only mixed returns on the GMI graph, and shows up only as lower values of the GMI.

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The major difference noted between the 1972 Landsat image and 1979 NOAA-n CMI graphs is the size of the Gran Val Swamp at the confluence of the Guachita and Saline Rivers. On the 1979 CMI contours the swamp area is apparently much reduced as indicated by the limited distribution of negative values. However, the basic feature shape is well defined by the lower CMI values that would be expected for a body of water mixed with trees and duckweed. A ground survey of this area in the spring of 1981 and during the 19791 flood confirmed that this area is characterized by cypress-oak bottoms and thick duckweed concentrations in the backwater. Duckweed is fairly common in slow-moving and standing waters in the mid-South (see Figures 6a and 6b).

The overall graph of the NOAA-n CMI contours when compared to the Landsat image is very similar. An estimate of the area within each CMI class can be generated by a digital plotter. Such equipment support has not been available to us either directly or indirectly.

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FIGURE 6a. Duckweed, a free-floating aquatic plant, wind-driven onto the shore of Black Bayou in North Louisiana. Photographed March 1981.

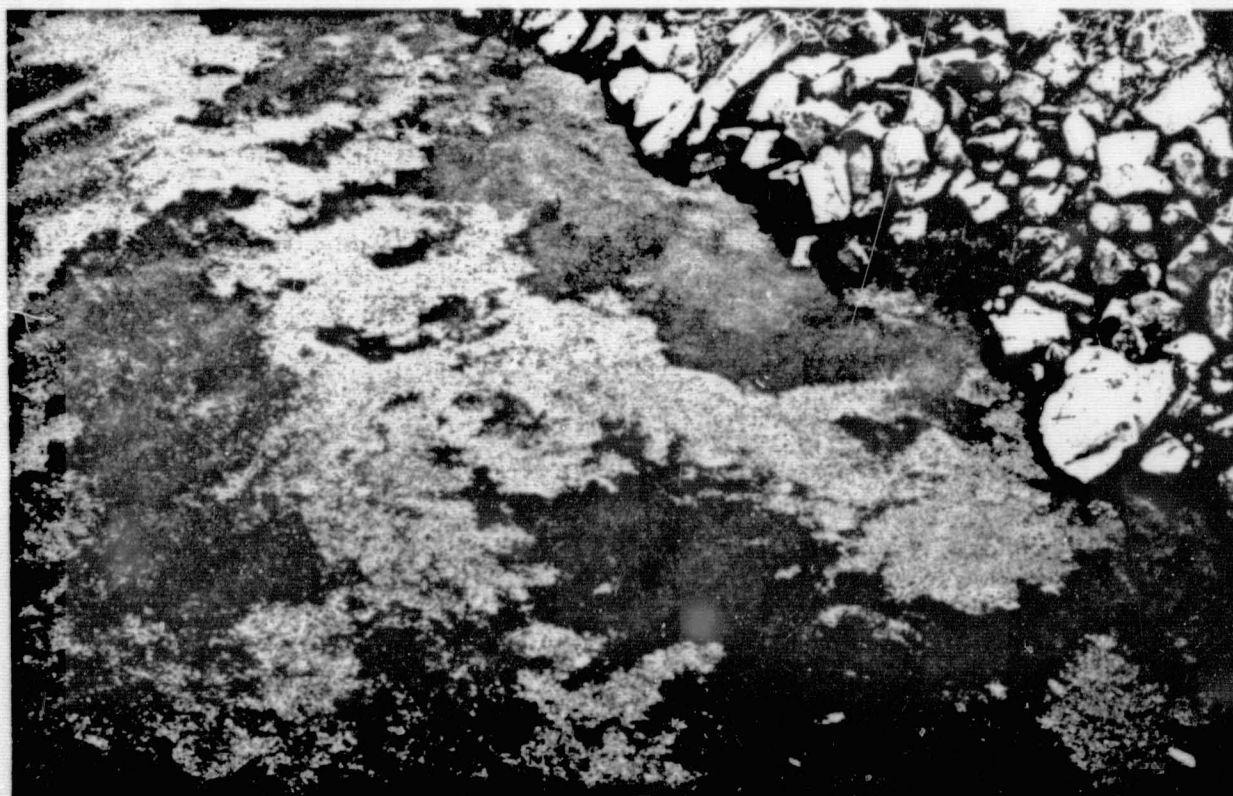


FIGURE 6b. Duckweed being carried by current in Black Bayou. We suspect the preponderance of this plant in waters of at least Southern Arkansas and North Louisiana may be the explanation ofr unexpectedly high GMI values over water areas in the 6 May 1979 NOAA image.

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Based upon regional observations and albedo characteristics of various surfaces, the following preliminary table of CMI class identifications is proposed:

TABLE 6
PROPOSED CMI CLASS IDENTIFICATIONS^c

<u>CMI Values</u>	<u>Type Surface Observed</u>
-2 to -3	Large uninterrupted cloud masses.
-3 to -2	Coastal waters, large lakes, large areas flooded by deeper water, large rivers.
+1 to -1	Shallow and turbid water bodies with no floating vegetation; large highways and railroads; very light bare or plowed soils.
1 to 4 (For swampy areas and floodplains)	Large areas of standing water; water with aquatic vegetation (cypress, duckweed, etc.); dormant and emergent sparse vegetation; swampy areas thick with Spanish moss.
4 to 8	Early emergent agricultural fields vegetation.
8 to 12	Coniferous forest.
12 to 20	Mature agricultural areas; dense healthy crops standing; thick healthy deciduous forests in full leaf.

^c It should be emphasized that our data sample is small and biased on data from U.S. Southwest, mid-South, and Southeast. A time bias of observations during the March-October period is also present. Nevertheless, we feel that this unrefined classification will assist users in discriminating surface returns and may lead to a more confident systemization of CMI's in the future.

CONCLUSIONS ON STUDY PURPOSE

Our team view is that the non-meteorological applications of the NOAA satellite families have been underemphasized and little investigated by the remote sensing community. This negative bias is understandable in the desire to obtain the maximum image linear resolution, narrow sensor viewing spectra, and precision image registration that has become the habit of Landsat users. In the reality of ailing Landsats in orbit, the possibility of an inter-regnum in future Landsat MES continuity, increasing user pressures for tighter temporal target imaging, and uncertain future Landsat funding levels and timing, this luxury of high-quality Landsat imagery may no longer be available as in the past.

Therefore, as an alternative - a complement - to Landsat, we invite further comparative studies of Landsat to NOAA imagery, and digital manipulation of NOAA imagery as a stand-alone for detecting fast-occurring and swiftly-changing environmental phenomena.

This study shows that NOAA-n imagery provides detailed non-meteorological scene information. Certainly the level of NOAA-n imagery detail is not that of a Landsat image. Nevertheless, for operational environmental monitoring users, the NOAA-n imagery may provide acceptable linear resolution and spectral isolation.

The possible criticism that this study contrasts two satellites' images from two different years is a two-edged sword - prima facie valid, but ignoring our purpose of stretching NOAA-n image information.

Special future attention should be given to denial or refinement of the proposed GMI class information definitions; to geometric understanding of image edges; to the effects of atmospheric attenuation; to attaining the maximum timeliness in product delivery using smooth software processing techniques; to interactive digital image manipulation; and to similar applications of GOES imagery.

We find no philosophical or technical conflicts in users utilizing both satellites' images: the NOAA-n for temporal continuity and "quick and dirty" reconnaissance; and, the Landsats for detailed, precision mapping of control and special interest areas.

Did we succeed in its narrow study purpose? We invite you - the potential user and professional critic - to review again for your discerning eye the Landsat and NOAA images (figures 2a and 2b - approximately same scale, 1:250,000) and the GMI values of the NOAA-6 scanlines (Figure 3).

References and Notes

1. Robinove, C.J. 1975. Worldwide disaster warning and assessment with Earth Resources Technology Satellites. U.S. Dept. of Interior Rpt. (IR) NC-47.
2. NOAA Satellite Task Force. 1980. Planning for a Civil Operational Land Remote Sensing Satellite System: A discussion of issues and options. U.S. Dept. of Commerce. 138 pp.
3. Siveton, W.E. 1980. Monitoring disaster areas via satellites. NASA-LRC Rpt. 12344. The weakness of this proposed application of active microwave (1-18 GHz) sensors is the requirements for emplacement of positional ground reflectors. Such a task might be difficult or impossible in areas of restricted access.
4. Perhaps the best current review of atmospheric applications of meteorological satellites are the three volumes below. Although written primarily for DMSP users, the applications and techniques should be familiar to NOAA-n users. The DMSP and NOAA-n sensors and buses are similar.

Fett, R.W. 1977-1981.
Navy Tactical Applications Guide: et al (4):
Vol. I (1977) Techniques and Applications of Image Analysis. Supplements.
Vol. II (1979) Environmental Phenomena and Effects. Supplements.
Vol. III (1981) North Atlantic and Mediterranean Weather Analysis-Meteorological Satellite Systems.

National Environmental Prediction Research Facility, Monterey, California.
5. Wiesnet, D.R.; McGinnis, D.F.; Pritchard, J.A. 1974. Mapping of the 1973 Mississippi River Floods by the NOAA-2 Satellite. Proc, 9th Intntl Symp. on Remote Sensing of Environment, 621-627.
6. Rohde, W.G.; Taranik, J.V.; Nelson, C.A. 1976. Inventory and Mapping of Flood Inundation using Interactive Digital Image Analysis Techniques. Proc, 2nd Pecora Mem. Symp, 131-143.
7. Allison, L.J; Schmugge, T.J. 1979. A hydrological analysis of East Australian floods using Nimbus-5 electrically scanning radiometer data. Bull, American Met. Soc, 60 (12): 1414-1427.

8. Launches of NOAA-C(7) through NOAA-J (14) are scheduled through September 1987, from the Western Test Range facility at Vandenberg AFB, CA. Later satellites in the family may be Shuttle-launched. Current launches are via the Atlas/PAM-D vehicle. ARGOS Newsletter, Centre Spatiale de Toulouse, Jan. 1981, p.4.
9. Details of the NOAA-6 and 7 (May 5, 1981, launch) satellites, orbital parameters, sensor characteristics, data formats and flows may be found in the respective users' guides:
 - a. NOAA-6: NOAA Polar Orbiter Data, Users Guide, Preliminary Version, NESS, December 1979.
 - b. NOAA-7: To be issued by NESS.
10. The evolution of the Gray-McCrory Index (GMI) applicable to both the GAC and LAC imagery of the NOAA-n series can be traced to their remote monitoring of the development of the 1980 drought in south Texas.

Gray, T.I. and D.G. McCrory. 1981. Meteorological Satellite Data. A tool to describe the health of the world's agriculture. AGRISTARS Rpt EW-N1-04042, 12 pp.

Gray, T.I. and D.G. McCrory. 1981. The Environmental Vegetative Index - A tool potentially useful for arid land management. Preprint, 15th Conference on Agriculture and Forest Meteorology, 4 pp.

The GMI has been adopted for daily operational use by the Crop Condition Assessment Division of the Foreign Agricultural Service of the USDA.
11. Perhaps the best review of Landsat-type imagery applications is contained in the Skylab reports: Skylab EREP Investigations Summary, NASA-JSC, SP399, 1978.
12. See: Muller, R.A. 1976.

Comparative Climatic Analysis of Lower Mississippi River Floods: 1927, 1973 and 1975.

Water Resources Bulletin, 12(6): 1141-1156. U.S. Army Corps of Engineers. The Flood of 1973. Mississippi River Commission, Vicksburg, MS. 62 pp.